Renewable and Sustainable Energy Reviews 32 (2014) 172–177

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Photovoltaic low power systems and their environmental impact: Yuma, Arizona, U.S.A. case study and projections for Mexicali, Mexico

Néstor Santillán Soto [a,*], O. Rafael García Cueto [a], Sara Ojeda Benítez [a], Alejandro Adolfo Lambert Arista [b]

[a] *Instituto de Ingeniería, Universidad Autónoma de Baja California, Blvd. Benito Juárez y Calle de la Normal s/n Col. Insurgentes Este C.P.21280, Mexicali, Baja California, México*

[b] *Facultad de Ingeniería, Universidad Autónoma de Baja California, México*

A R T I C L E I N F O

Article history:
Received 7 September 2012
Received in revised form
26 August 2013
Accepted 29 December 2013
Available online 30 January 2014

Keywords:
Mitigation
Solar radiation
Potential energy
Greenhouse gases
Sustainable cities

A B S T R A C T

This article presents a proposal for the implementation of photovoltaic systems in homes located in Mexicali, Mexico. With exhibition of new insulation and different consumption characteristics. The photovoltaic low power system is proposed as a type of electrical supply that helps in reducing the environmental impact of generating energy by burning fossil fuels. A photovoltaic system installed in the city of Yuma, Arizona in the United States, which supplies the electrical needs to a building is selected as a reference for solar resource use. Energy use improvement and consumption costs are calculated, and the equivalent amounts of greenhouse gases, not generated since solar technologies were implemented are determined. Furthermore, comparisons of the solar potential between Yuma and Mexicali show that the Mexican city has a higher annual solar potential, so the applicability of this solar technology is too feasible in Mexicali.

Contents

1. Introduction

The world faces serious problems related to climate change. CO_2 is a major contributor to the global warming. Therefore, implementation of strategies to achieve a significant reduction in the global emissions is required [1]. A permanent increase in the overall electricity demand is a constant around the world. The availability, cost and sustainability of energy resources have caused instabilities in the supply and production of energy in

* Corresponding author. Tel./fax: +52 686 5664150.
E-mail addresses: nsantillan@uabc.edu.mx (N. Santillán Soto), rafaelcueto@uabc.edu.mx (O.R. García Cueto), sara.ojeda.benitez@gmail.com (S. Ojeda Benítez), alambert@uabc.edu.mx (A.A. Lambert Arista).

1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2013.12.051

recent years. Moreover, environmental damage has indicated the need for new energy models [2].

The climate scenarios generated by the Intergovernmental Panel on Climate Change [3,4] have exerted strong pressure on experts in the fields of electrical engineering, electronics and mechanics to develop systems using renewable energy resources, particularly solar and wind energy [5] and especially in developed countries [6]. The interest is due to the fact that these clean energy resources can lessen the effects of climate change caused by the use of energy based on fossil fuels, which produces pollutants such as CO_2, among others. Potential methods to address this global problem in the future include the use of photovoltaic and wind systems. In the long term, these systems will constitute a portion of the alternatives that will mitigate the amounts of CO_2 emissions [1,7,8,9,10]. In the past decade, only 13.61% of the worldwide energy demand was supplied by renewable resources [11]. Photovoltaic systems, especially those connected to a network, have experienced strong growth over the past five years, mainly in developed countries. In these countries during 2006, approximately 1.5 GW of photovoltaic capacity was installed, representing an increase of 34% over the previous year. In 2007, a 40% increase of the installed photovoltaic capacity resulted in a total capacity of 7.8 GW [12], indicating that there should be interest not only in renewable energy itself, but also in the related.

This installed systems contrasts with the global photovoltaic market produced which in 2007 produced 2392 MW and Europe accounted for 69% of this. By 2008 the market produced a total of 5559 MW, of which Europe accounted for 81%, though as a result of changes in the Korean and US markets the Asian and American markets also saw a large degree of growth, with the US accounting for 6.2% of the total global market. If these figures are broken down then it becomes clear that the majority of the global market is centered in Spain, Germany, the US and Korea, these four countries, while Belgium, the Czech Republic, Japan and Portugal are currently playing catch up. Globally accumulated PV installed capacity in 2008 has reached 15 GW and European countries accounted for 65% of this, more than 9 GW, while Japan and the US followed closely in 2nd and 3rd place (with Japan accounting for 15% or 2.1 GW and the US accounting for 8% or 1.2 GW) [13].

Urbanization has been the dominant global trend since the middle of the last century, resulting in cities exerting a polarizing effect, reflecting a social product where both poverty and wealth are found, in addition to economic, social and political opportunities [14]. In cities, energy dependence is directly proportional to quality of life. This concept has not always been well understood, as it is often based on distractors and satisfactors and therefore on a waste of energy [15]. It is no wonder, then, that the nations of the world, worried about a polluted environment and a society that has depended heavily on fossil fuels since the late 1880s, have proposed the concept of sustainability, which according to Bruntland [16], indicates that a sustainable society would be one that meets its present needs without compromising resources for future generations. It has been 25 years since this definition was provided, and the dialectical discussion about it continues today. Therefore, it appears the notion of sustainability is a long-term goal [17,18].

In Mexico, currently it is necessary to focus on the sustainable city concept, as it is imperative that we plan these types of cities. One of the essential questions that we must ask ourselves is whether we are able to reorient urban ecosystems that have been built haphazardly, and in a relatively short period of time progressively towards a stage characterized by health, order and energy efficiency. One of the key questions regarding reorienting a city toward sustainability is as follows: is electrical energy sufficient and used efficiently in a way that does not compromise future generations? Answering this question involves implementing strategies such as the proposed Net Zero Energy Buildings [19,20], which would generate as much energy as they consume, whether measured on an annual or monthly basis. The main idea behind this type of construction is that it can meet its energy needs with renewable, locally available and inexpensive sources, making it necessary to evaluate the energy potential of the source of interest in each region. One of the characteristics of Net Zero Energy Buildings is that these buildings both significantly reduce their energy needs and make adjustments for consumption to be reduced to a minimum, in addition to occasionally interacting with conventional supplies [21,22].

Another factor to be considered is construction materials. Todorovis [23] argues that construction should use materials found in the immediate environment, especially renewable urban materials that respect climate characteristics, making it necessary to develop energy efficient construction projects that meet high thermal standards and use eco-materials [24]. However, this is not currently the case in cities around the world, which further exacerbates the problem of supplying residential electricity. Residential areas are affected not only by the planning and design of constructions, but also by the density of the green canopy and the complex influence of anthropogenically generated heat [25]. Urbanization that is not linked to sustainability alters the native ground cover in a region and leads to a modified thermal climate. Different sets of micro- and meso-scale climates are therefore generated, giving rise to the well-known urban heat island (UHI) effect, which has been studied extensively in several cities around the world [26,27,28,29] and has practical implications for energy and water conservation, human health and comfort, pollutant dispersion and local air circulation [30,31]. All of these impacts on a city and its inhabitants can be mitigated by following proposals of power generation using natural resources, such as solar energy, which is the most abundant, inexhaustible and cleanest of all the renewable energy sources known to exist. The amount of solar power intercepted by the Earth is approximately 1.8×10^{11} MW, which exceeds the current rate of all energy consumption [32]. Moreover, covering 0.16% of the land on earth with solar conversion systems with a 10% efficiency would provide 20 TW of power, which is nearly twice the world consumption of fossil fuel-based energy [33].

Considering all of these factors, the present study was proposed with the following aims: (1) to evaluate the solar potential in the city of Mexicali, B.C., Mexico, using global solar radiation measurements; (2) to compare this potential with that of the city of Yuma, AZ, USA, where solar resources are currently used to power a building on the main Arizona Western College (AWC) campus; and (3) to conduct an analysis in terms of power consumption and economic and environmental impacts of the possible use of solar resources in Mexicali, B.C., and their relationship with respect to zero energy use compared with what actually occurs in the city of Yuma, AZ.

2. Methodology

The study was conducted in northwestern Mexico at the border with the United States using two cities, one in Mexico (Mexicali, B.C.) and the other in United States (Yuma, AZ), as a case study. The methodology employed in the study is presented in three sections: (1) Measurements of the solar resources in Mexicali, (2) Measurements of the solar resources in Yuma and (3) Analysis of the associated electricity demand, cost of household consumption and environmental benefits.

2.1. Measurements of the solar resources in Mexicali

This stage was developed based on radiometric measurements recorded in Mexicali through the weather station of the Institute

of Engineering of the Universidad Autónoma de Baja California, Campus Mexicali (Baja California Autonomous University, Mexicali Campus) in 2010. Four months (January, April, July and November) that were representative of the four seasons were selected in which to perform the measurements, with 30 days of radiometric records being reported for each month on average. This recorded radiometric information was used and subsequently processed in Excel to be compared with the corresponding Yuma database for the same periods.

The following types of radiometric hardware and software from the meteorological station at Mexicali were used to perform measurements:

- Global solar radiation sensor star pyranometer 240-8101.
- Global solar radiation sensor pyranometer CMP3.
- CR10 Datalogger (Campbell Scientific).
- SCWIN (Program Generator, Campbell Scientific).
- PC200W 4.0 (Campbell Scientific program for monitoring and collecting data).

2.2. Measurements of solar resources in Yuma

At this stage of the analysis, data from the low power system located in the city of Yuma, AZ, currently being used at the Arizona Western College Main Campus [34] were used. To perform the comparative analysis, corresponding data from the same study periods obtained in Mexicali were included. The energy equivalents and emissions that were not generated were documented from the low power system database. The radiometric data for both cities were processed and projected graphically and in the form of tables for further analysis.

2.3. Analysis of electricity demand, the cost of household consumption and environmental benefits

Thermal evaluation was performed for middle income homes with an area of 134 m^2, taking into account methodology and results previously reported for the city of Mexicali [35,36] through dynamic simulations in the DOE-2.1 thermal loads simulator, which has been validated for use in thermal assessments of buildings and simulation studies [37]. This methodology has been used in recent decades by different experts [38,39]. The types of homes included in the analysis were labeled as basic homes and Net Zero homes.

The total number of households that can use the power generated by the photovoltaic system installed in Yuma was calculated by considering the amount of energy generated in 2010 and dividing it by the consumption of both types of homes tested for Mexicali. The electricity consumption costs for this city in the same year were realized by considering the cost per kWh in three categories: basic, intermediate and excessive. The costs of electricity consumption correspond to the archives of the Federal Electricity Commission for the year 2010 [40], starting with the basic cost, which corresponds to 0.709 Mexican pesos, for consumption of up to 53.17 kWh, followed by an intermediate cost of 1.181 Mexican pesos for up to 125 kWh and an excessive cost of 2.497 Mexican pesos, with the last category representing up to 200 kWh of residential consumption. The amount of greenhouse gases (GHG) that were not generated was obtained from the electronic monitoring portal of the low power system, as were the energy equivalents.

3. Results

This section presents the results of the solar resource assessment for both cities and projections for Mexicali, B.C., in economic and environmental terms, of the possible use of technologies employing solar resources as an energy source.

3.1. Solar radiation in Mexicali, Mexico

Fig. 1 presents the irradiation results for year 2010 of the four seasons: winter, spring, summer and fall in the city of Mexicali. It can be observed that the spring and summer seasons present the highest values due to the geographic location of this region.

3.2. Solar radiation in Yuma, U.S.A.

Fig. 2 shows the solar radiation results for the same seasonal periods for the city of Yuma, U.S.A. The values for the warm seasons are also higher than for the cold periods in this area, although the difference is less pronounced for this city.

A comparison of the average solar potential between the two cities for month, representative of each season, in 2010 is presented in Fig. 3. This comparison shows overall that the city of

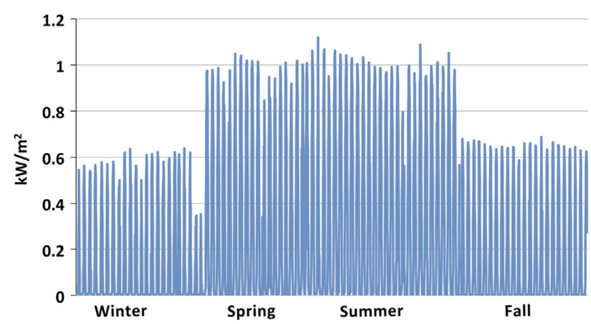


Fig. 1. Solar radiation in Mexicali, Mexico in 2010.

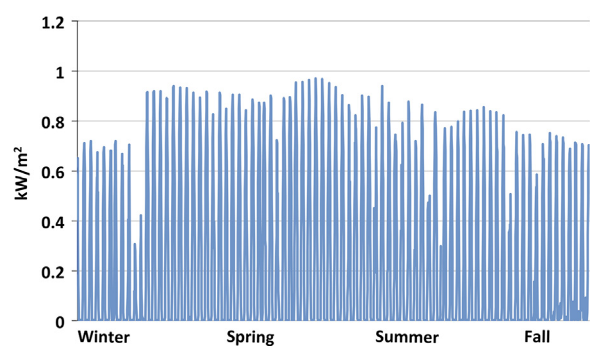


Fig. 2. Solar radiation in Yuma, U.S.A. in 2010.

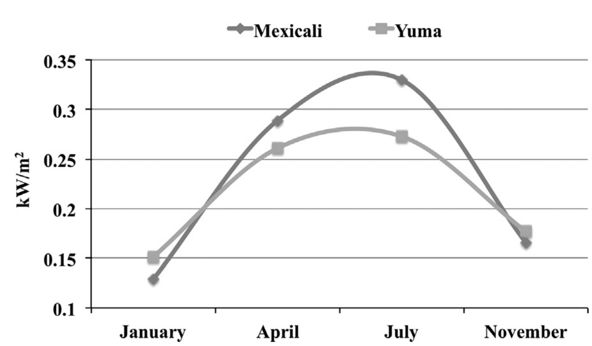


Fig. 3. Comparison of average irradiation by month between Mexicali and Yuma for 2010.

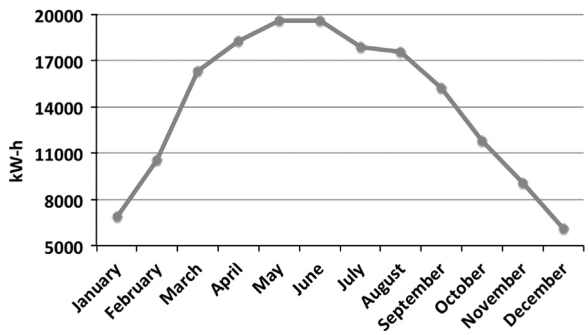


Fig. 4. Production of the low power system of 105.6 kW DC (Arizona Western College Solar Array, Yuma, AZ, EEUU, 2010).

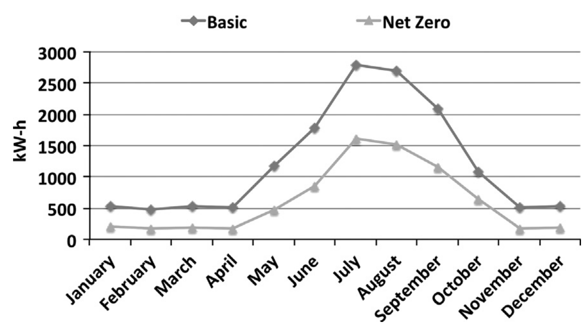


Fig. 5. Comparative consumption of homes in Mexicali, 2010.

Mexicali has all of the radiometric advantages necessary to install photovoltaic or solar collection systems, given that its potential considerably exceeds that of the city of Yuma, which currently uses this resource.

Fig. 4 provides the production data for the low power system. Production increases in the warmer months due to the high irradiation and energy demand that prevails in the warm seasons. It was observed that the cumulative generation of the low power system was 168,801 kWh for 2010 alone. It is also noted that this system began in January 2009, and its cumulative generation over 3 years of operation is approximately 555,699.4 kWh.

Fig. 5 shows the electricity consumption behavior of each household, which corresponds to the results reported by Calderon (2011). The behaviors of the two types of homes are similar, but the power consumption is considerably higher in the homes where thermal insulation is not considered.

3.3. Analysis of electricity consumption, costs and GHG emissions not generated

This section presents the results of the analysis performed to compare the basic and Net Zero homes in Mexicali. The variables analyzed were electricity consumption, costs, GHG not emitted and energy equivalents.

Regarding the GHG variable, Table 2 shows the amount in kg of GHG not generated since solar technologies were implemented at AWC.

4. Discussion

The results obtained from the solar resource assessment performed for the two cities included in the study allow us to highlight several particular findings. In the city of Mexicali, during the warm season of the year, solar energy potential exceeds 1000 W/m^2, while for Yuma this threshold is never reached during the year. However, the solar energy potential is higher for Yuma in the cold seasons, and more homogeneous behavior is observed. These differences can be observed more clearly when comparing the averages for each season, as shown in Fig. 3. This graph shows that there is a higher annual potential in the city of Mexicali. These differences may be explained by the amounts of cloud cover and precipitation observed in 2010. In Yuma, the annual rainfall was 62 mm, while in Mexicali, it was 45.25 mm. Additionally, Yuma presented twice the number of cloudy days than those observed in Mexicali, which is important in quantifying the potential energy available from solar resources locally.

There are also differences between the homes with regard to electricity consumption (Fig. 5), with significantly lower consumption being observed for the Net Zero-type homes compared to the basic homes. The most demanding months with regard to electricity consumption occur from May to October because Mexicali is one of the hottest cities in Mexico, presenting average maximum temperatures of 42.2 °C in July, receiving 90% of the maximum potential hours of daylight each year and averaging 75 mm of rain annually. On July 28th 1995, a maximum temperature of 52 °C was observed in Mexicali [41]. In this city, homes without proper insulation (middle income homes used as the basic case) are primarily causing a greater energy demand.

It is also notable that the system installed at the AWC campus in 2010 generated 168,801 KWh of energy (Fig. 4), which translates into the following equivalents if we divide this total by the annual consumption of the homes analyzed, indicating that power can be provided to 11.4 middle income, basic homes and to 22.9 homes of the Net Zero type.

In Table 1, the cost analysis for each type of home studied was determined. It can be seen that the year-round demand for the basic case at the excessive level impacts the total consumption cost, while the Net Zero homes require no surplus for 5 months of the year. It is also notable that Zero Net homes consume 40.99% less of the surplus compared to the basic homes. Overall, the cost of electricity consumed in a basic house is 2.2 times higher than in the Net Zero type.

Furthermore, as documented in the Arizona Western College Solar Array system, the amount of GHG not generated since the implementation of the low power system (Table 2) is equivalent to the energy required to keep a television running for 3,870,080 h, the energy to power 4283 computers for a year, the average pollution emitted by a passenger vehicle over 69 years and the energy needed to power 30 households for a year [33]. Based on these findings, further lines of research emerge that need to be addressed to generate credit schemes as well as to determine the financing and payback time for a photovoltaic farm to be economically profitable and mitigate CO_2 emissions [42] because in some cases, the life cycle of Net Zero homes due to the high costs of implementing solar technologies does not allow for the investment to be paid back [43].

The scope of this study should be extended, including more types of homes, enhancing the comparative analyses with additional years of data and generating more results to promote new feasible economic proposals, thus allowing the proposal of cities to be designated sustainable cities. Additionally, it will be of interest to incorporate evaluation of the wind potential in the city with respect to utilizing low power wind resources, either via hybrid or single-source systems.

5. Conclusions

This research contributes individual indicators related to low power photovoltaic technologies currently used in a few kilometers from Mexicali, which can be also used in this city because it presents the required conditions for its implementation. Further

Table 1
Comparison of consumption in kWh in the homes tested in Mexicali.

Month	Basic homes					Net Zero home				
	Consumption kWh[b]	Basic cost[a]	Intermediate cost[a]	Excessive cost[a]	kWh[b] Excessive	Consumption kWh[a]	Basic cost[a]	Intermediate cost[a]	Excessive cost[a]	kWh[b]Excessive
January	521.86	53.17	147.62	803.68	321.86	208.26	53.17	147.62	20.63	8.26
February	476.98	53.17	147.62	691.62	276.98	175.3	53.17	147.62	0.00	0
March	529.91	53.17	147.62	823.79	329.91	185.26	53.17	147.62	0.00	0
April	510.63	53.17	147.62	775.64	310.63	175.61	53.17	147.62	0.00	0
May	1183.71	53.17	147.62	2456.32	983.71	465.26	53.17	147.62	662.35	265.26
June	1789.85	53.17	147.62	3969.86	1589.85	857.61	53.17	147.62	1642.05	657.61
July	2782.46	53.17	147.62	6448.40	2582.46	1606.26	53.17	147.62	3511.43	1406.26
August	2694.31	53.17	147.62	6228.29	2494.31	1512.26	53.17	147.62	3276.71	1312.26
September	2088.85	53.17	147.62	4716.46	1888.85	1158.61	53.17	147.62	2393.65	958.61
October	1084.86	53.17	147.62	2209.50	884.86	635.26	53.17	147.62	1086.84	435.26
November	510.48	53.17	147.62	775.27	310.48	177.61	53.17	147.62	0.00	0
December	530.06	53.17	147.62	824.16	330.06	194.26	53.17	147.62	0.00	0
Total	**14,703.96**	**638.04**	**1771.44**	**30,722.99**	**12,303.96**	**7351.56**	**638.04**	**1771.44**	**12,593.67**	**5043.52**
Total annual consumption in pesos 33,132.47					Total annual consumption in pesos **15,003.15**					

[a] Electric energy consumption cost, CFE 2010.
[b] Annual consumption per household in Mexicali, Calderon 2011.

Table 2
Cumulative GHG not generated.

GHG	Quantity/kg
CO_2	313,482.05
NO_x	520.78
SO_2	859.55

estimates suggest that these technologies can be even better applied in the city of Mexicali. If these types of technologies are applied in cities with a sufficient solar potential, the additive effect of these efforts can contribute to reducing emissions of greenhouse gases and, thus, global warming, which is currently having negative effects throughout the world. It should not be just a recommendation, it is imperative to turn to other perspectives in order to achieve environmentally benign sustainable energy programs and renewable energy sources should be promoted in every stage. This will create a strong basis for the short- and long-term policies. The States should be promoted it, the individual participants should be encouraged and the generation of photovoltaic energy trade and photovoltaic cell production should be incentives. People who can be produced more facilitated their own electricity. Various activities should be organized to increase public awareness and applications. Public offices have an important role for this situation [44]. Finally, it is important to highlight the efforts of Arizona Western College to propel the city of Yuma to be more sustainable, as their photoelectric production had increased to 5 MW by 2011 [45]. Other institutions are doing measurements of the solar irradiation in order to design solar systems alternatives to get the Net Zero concept applied to its facilities [46].

References

[1] Abounmahboub T, Schaber K, Wagner U, Hamacher T. On the CO2 emissions of the global electricity supply sector and the influence of renewable power-modeling and optimization. Energy Policy 2012;42:297–314.
[2] Castillo-Cagigal M, Matallanas E, Gutierrez A, Monasterio-Huelin F, Caamañо-Martin E, Masa-Bote M, et al. Heterogeneous collaborative sensor network for electrical management of an automated house with PV energy. Sensors 2011;11:11544–59, http://dx.doi.org/10.3390/s111211544.
[3] IPCC. Climate Change. The Physical Science Basis. Summary for Policymakers. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, editors. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. . Cambridge University Press. Cambridge, United Kingdom and New York, USA; 2007. p. 996.
[4] IPCC special report on renewable energy sources and climate change mitigation. In: Edenhofer O, Pichs-Madruga R, Sokona Y, Seyboth K, Matschoss P, Kadner S, Zwickel T, Eickemeier P, Hansen G, Schlömer S, von Stechow C, editors. Prepared by Working Group III of the Intergovernmental Panel on Climate Change.]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA; 2010. p. 1075.
[5] Kaldellis JK, Zafirakis D, Kavadias K. Minimun cost solution of wind-photovoltaic based stand-alone powersystems for remote consumers. Energy Policy 2012;42:105–17.
[6] Bodas Freitas IM, Dantas E, Iizuka M. The Kyoto mechanisms and the diffusion of renewable energy technologies in the BRICS. Energy Policy 2012;42:118–28.
[7] Alsema EA, Nieuwlaar E. Energy viability of photovoltaic systems. Energy Policy 2000;28:999–1010.
[8] Choi DG, Thomas VM. An electricity planning model incorporating demand responce. Energy Policy 2011;42:429–41.
[9] Wang Z, Yang Z, Zhang Y, Yin J. Energy technology patents-CO_2 emissions nexus: an empirical analysis from China. Energy Policy 2012;42:248–60.
[10] Wen-Jung Ch Hurng-Liahng J, Jinn-Chang W, Kuen-Der W, Ya-Tsung F. Active islanding detection method for the grid-connected photovoltaic generation system. Electr Power Syst Res 2010;80:372–9.
[11] Goldemberg J. Ethanol for a sustainable energy future. Science 2007;315:808–10.
[12] Moraes TO, Oliveira FD, Alves CDAS. Distributed photovoltaic generation and energy storage systems: a review. Renew Sustain Energy Rev 2010;14:506–11.
[13] Liou HM. Overview of the photovoltaic technology status and perspective in Taiwan. Renew Sustain Energy Rev 2010;14:1202–15.
[14] OECD Environmental Outlook to 2030. Organization Economic Cooperation and Development, París, Francia 2008. p. 520. 978-92-64-04048-9.
[15] Bulkeley H, Betsill M. Cities and climate change: urban sustainability and global environmental governance. New York USA: Routledge; 2003.
[16] Bruntland G. Our common future: The World Commission on Environment and Development. UK: Oxford University Press; 1987.
[17] Phdungsilp A. Futures studies backcasting method used for strategic sustainable city planning. Futures 2011;43:707–14.
[18] Höjer M, Gullberg A, Pettersson R. Backcasting images of the future city—time and space for sustainable development in Stockholm. Technol Forec. Soc Change 2011;78:819–34.
[19] Xing Y. Zero carbon buildings refurbishment––a hierarchical pathway. Renew Sust Energy Rev 2011;15:3229–36.
[20] Zabaneh GA. Zero net house: preliminary assessment of suitability for Alberta. Renew Sust Energy Rev 2011;15:3237–42.
[21] Marszal AJ, Heiselberg P, Bourrelle JS, Musall E, Voss K, Sartori I, et al. Zero energy building – a review of definitions and calculation methodologies. Energy Build 2011;43:971–9.
[22] Sartori I, Dokka TH, Andresen I. Proposal of a norwegian zeb definition: assessing the implications for design. J Greenbuild 2011;6:133–50.
[23] Todorovic MS. BPS, energy efficiency and renewable energy sources for buildings greening and zero energy cities planning. Energy Build 2012;48:180–9 (2012).
[24] Radulovic D, Skok S, Kirincic V. Energy efficiency public lighting management in the cities. Energy 2011;36:1908–15.

[25] Yang F, Lau S, Qian F. Urban design to lower summertime outdoor temperatures: an empirical study on high-rise housing in Shanghai. Build Environ 2011;46:769–85.
[26] Voogt JA, Oke TR. Thermal remote sensing of urban climates. Remote Sens Environ 2003;86:370–84.
[27] Chen XL, Zhao HM, Li PX, Yin ZY. Remote sensing image-based analysis of the relationship between urban heat island and land use/cover changes. Remote Sens Environ 2006;4:133–46.
[28] Garcia COR, Jáuregui E, Toudert D, Tejeda A. Detection of the urban heat island in Mexicali, B.C., Mexico and its relationship with land use. Atmosfera 2007;20:111–31.
[29] Picón A, Vázquez R, González J, Luvall J, Rickman D. Use of remote sensing observations to study the urban climate on tropical coastal cities. Rev Umbral 2009;1:218–32.
[30] Roth TM. Satellite derived Urban Heat Islands from three coastal cities and the utilization of such data in Urban Climatology. Intl J Remote Sens 1989;10:1699–720.
[31] Santamouris M. Using cool pavements as a mitigation strategy to fight urban heat island—a review of the actual developments. Renew Sustain Energy Rev 2010;26:224–40.
[32] Parida B, Iniyan S, Goic R. A review of solar photovoltaic technologies. Renew Sustain Energy Rev 2011;15:1625–36.
[33] Dincer F. Overview of the photovoltaic technology status and perspective in Turkey. Renew Sustain Energy Rev 2011;15:3768–79.
[34] Arizona Western College Solar Array (2012).〈http://view2.fatspaniel.net/PV2Web/merge?view=PV/standard/Simple&eid=144395〉. (consultation date April 03 2012).
[35] Calderón VR. Modelo de metabolismo energético, a partir del consumo eléctrico de la vivienda económica de Mexicali, B. C. Tesis de doctorado. Facultad de arquitectura y diseño, Instituto de investigaciones sociales. Universidad Autónoma de Baja California. Mexicali, México. 2011 p. 158.
[36] Calderón R, Arredondo J, Gallegos R, Mayagoitia F. Electrical consumption and CO_2 reduction using saving systems and thermal insulation applied to dwellings in arid lands of Mexico. Inf Tecnol 2011;22:69–78.
[37] Sullivan R. Validation Studies of the DOE-2 Building, Energy Simulation Program. Lawrence Berkeley National Laboratory, University of California Berkeley; 1998.
[38] Vreenegoor R. de Vries, B. Hensen, Energy saving renovation: analysis of critical factors at the building level, Actas del 5o Congreso sobre ciudad sustentable, regeneración urbana y sustentabilidad, ISSN: 1743-3541, 978-1-84564-128-3, Skiathos, Grecia; 2008. p. 653–62.
[39] Garrison M. The 2007 Solar D House, Actas del Congreso regeneración urbana y sustentabilidad Grecia; 2008. p. 355–7.
[40] CFE Aviso de recibo. Comisión Federal de Electricidad. Factura de consumo. Mexicali, B.C.;2010. p.1.
[41] García COR, Santillán SN. Modeling extreme climate events: two case studies in México. climate models. Rijeka, Croatia: INTECH; 2012; 145.
[42] Deng S, Dalibard A, Martin M, Dai YJ, Eickec U, Wang RZ. Energy supply concepts for zero energy residential buildings in humid and dry climate. Energy Convers Manage 2011;52:2455–60.
[43] Leckner M, Zmeureanu R. Life cycle cost and energy analysis of a Net Zero Energy House with solar combisystem. Appl Energy 2011;88:232–41.
[44] Dincer F. Overview of the photovoltaic technology status and perspective in Turkey. Renew Sustain Energy Rev 2011;15:3768–79.
[45] Arizona Wester College 2011. 〈http://www.azwestern.edu/Marketing_and_PR/solar_array.html〉. (consultation date December 06 2011).
[46] Rosiek S, Batlles FJ. Renewable energy solutions for building cooling, heating and power system installed in an institutional building: case study in southern Spain. Renew Sustain Energy Rev 2013;26:147–68.